Interactive One-Shot Spatially Resolved Real-Time Velocity Imaging

D. Lee[1], J. M. Santos[1], A. B. Kerr[1], B. S. Hu[2], and J. M. Pauly[1]
[1]Electrical Engineering, Stanford University, Stanford, California, United States, [2]Palo Alto Medical Foundation, Palo Alto, California, United States

INTRODUCTION: Doppler ultrasound is the most commonly used imaging modality in diagnosing cardiovascular diseases but it suffers from limited acoustic window and difficult image alignment. MR Doppler [1-3] has potential to improve upon Doppler ultrasound [4,5]. It resolves velocity distribution in 1D space and velocity in real-time by applying 1D readout gradient after 2D cylindrical excitation pulse. However, fixed excitation and readout gradients design has significant limitation in valve flow imaging application. We developed on-the-fly design of both pencil beam excitation and oscillating readout waveform to improve the performance of MR Doppler for different clinical scenarios.

THEORY: MR Doppler becomes a more effective examination tool when it is integrated into real-time MR system which gives more accurate prescription capability through real-time localization, acquisition, and display [4]. When designing a pencil beam excitation, beam width should be small enough not to excite vessel wall and sidelobes should reside outside body or coil sensitivity region [3,6]. For readout, resolution and FOV in velocity and spatial dimensions need to be chosen to have proper range of velocity spectrum and the resultant readout time should be short enough to avoid signal dephasing. When imaging valves, desirable excitation geometry and peak velocity value is very dependent on target and subject. For instance, while normal peak velocities at mitral and tricuspid valves are less than 2m/s and 0.8m/s respectively, regurgitant flow at tricuspid and stenotic flow at aorta ranges 3~5m/s. We can find the optimal velocity FOV (FOV_v) starting from large one with crude spectrum and ending with just enough FOV_v so that we can have the best resolution we can get with a given readout time. Similarly, we can switch from a thick to thin beam excitation. By allowing the on-the-fly design capability, we can efficiently refine waveforms while examining (Figure 1).

METHODS: The RTHawk real-time MR imaging system [7] allows on-the-fly reconfiguration of gradient waveforms and excitation pulses as well as real-time localization capability. Waveform generation and image reconstruction modules were integrated into RTHawk system and basic user interface was implemented by which operator changes sequence parameters in an interactive way. Currently, it has the capability of variable density excitation k-space excitation [6] and echo-shifted interleaved multi-shot acquisition [8] in addition to changing conventional MR Doppler imaging parameters.

RESULTS AND CONCLUSION: Excitation and readout waveforms can be designed and loaded on scanner within a fraction of a second and we successfully acquired images while switching designs in both excitation and readout waveforms (GE 1.5T Signa scanner, Figure 3). This interactive on-the-fly design approach improves flexibility of the comprehensive real-time MRI examination in the sense that it enables a customized exam for each subject by changing parameters to opt for the best trade-off on site.

References

[1] Hu BS et al., Magn. Reson. Med., 30:393-398 (1993)
[2] Irarrazabal, P et al., Magn. Reson. Med., 30:207-212 (1993)
[3] Luk Pat, GT et al., Magn. Reson. Med., 40:603-613 (1998)
[4] DiCarlo, JC et al., ISMRM 10th, 1801 (2002)
[5] Macgowan, CK et al., J. Magn. Reson. Imag., 21:297-304 (2005)
[6] Lee, D et al., ISMRM 12th, 1898 (2006)
[7] Santos, JM et al., IEEE EMBS 26th, 1048-1051 (2004)
[8] Kerr, AB et al., SCMR 10th, in print (2007)

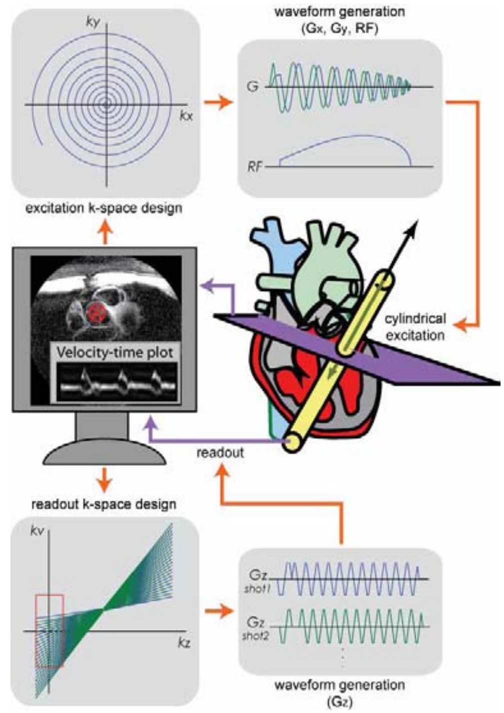

Figure 1. Interactive MR Doppler: operator can change excitation pulses and readout gradient waveforms in the course of examination.

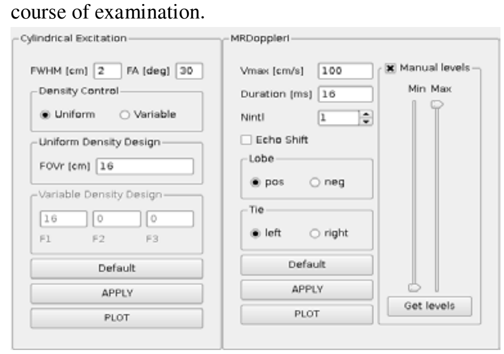

Figure 2. User interface of interactive MR Doppler

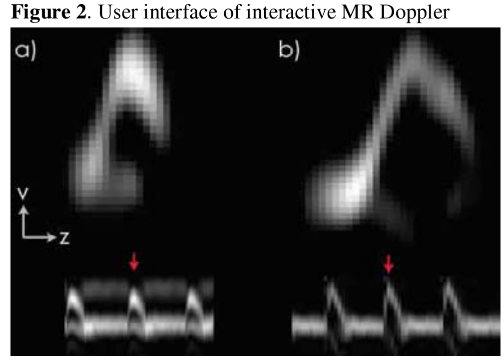

Figure 3. Readout waveform was redesigned and applied while observing aortic valve: snap shot images in v, z at systole (red arrow) (a) v_{max} = 2m/s with 16ms single shot of 16ms readout (b) v_{max} = 1.2m/s with 3 shots, 8 ms readouts